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A Search for wide visual companions of exoplanet host stars. The Calar Alto Survey

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Abstract. We have carried out a search for co-moving stellar and substellar companions around 18 exoplanet host stars with the infrared camera MAGIC at the 2.2m Calar Alto telescope, by comparing our images with images from the all sky surveys 2MASS, POSS I and II. Four stars of the sample namely HD 80606, 55 Cnc, HD 46375 and BD-10°3166, are listed as binaries in the Washington Visual Double Star Catalogue (WDS). The binary nature of HD 80606, 55 Cnc, and HD 46375 is confirmed with both astrometry as well as photometry, thereby the proper motion of the companion of HD 46375 was determined here for the first time. We derived the companion masses as well as the longterm stability regions for additional companions in these three binary systems. We can rule out further stellar companions around all stars in the sample with projected separations between 270 AU and 2500 AU, being sensitive to substellar companions with masses down to $\sim 60\,\mathrm{M_{Jup}}$ (S/N = 3). Furthermore we present evidence that the two components of the WDS binary BD-10°3166 are unrelated stars, i.e this system is a visual pair. The spectrophotometric distance of the primary (a K0 dwarf) is $\sim$67 pc, whereas the presumable secondary BD-10°3166 B (a M4 to M5 dwarf) is located at a distance of 13 pc in the foreground.

Key words: stars: binaries: visual, individual (HD 80606, HD 46375, 55 Cnc)

1. Introduction

More than 100 stars are already known to host exoplanets. Detected by radial velocity searches, theses planets orbit their host stars on relative close orbits with semi-major axes smaller 5 AU. Some of these exoplanets were found in binary systems, in which the exoplanet host star is mostly the more massive primary star. First statistical differences between planets orbiting single stars and planets located in binary systems were already reported by Zucker & Mazeh (2002) and Eggenberger et al. (2004), using samples of 9 and 15 binaries, respectively. In particular, planets with orbital periods shorter than 40 days exhibit a difference in their mass-period and eccentricity-period distribution. Mugrauer et al. (2005b) updated and extended the sample of binaries among the exoplanet host stars (21 binaries) and confirmed the reported statistical differences for short period planets. These statistical differences between planets orbiting single stars and planets residing in a binary systems might be an implication of the host star multiplicity.

Today only four of the binary systems with exoplanets are known to have small projected separations of the order of 20 AU (HD 188753, γ Cep, HD 41004 and Gl 86). Due to the proximity of the stars in these four stellar systems, they are a challenge for planet formation theories (core accretion and gravitational collapse scenario). In these systems the size of a protoplanetary disk around the exoplanet host star is truncated by its companion star to only a few AU and does not extend beyond the ice line (Pichardo et al. 2005). Furthermore, objects revolving around the exoplanet host star farther outside are perturbed by the secondary star and are not longterm stable, i.e. finally these objects will be ejected from the system or collide with one of the two stars (Holman & Wiegert 1999). Therefore, planets orbiting a component of a close binary system should be formed and reside only in the

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adjacency of their parent star. On the other hand, close to the star, within the ice line, the core accretion (lack of solid material to form the planet core in a solar minimum mass nebula) as well as the gravitational collapse scenario (high disk temperature dumps gravitational instability) cannot explain the formation of gas giant planets (Jang-Condell 2005).

Nevertheless, there are ways around this problem. The secondary star could excite density waves in the disk, increasing the surface density in some parts of the disk, leading to planet formation via gravitational instability. Or, the planet bearing disk might be different from the disk of our own solar system. If disks of the same mass differ only in their angular momentum, such that in smaller disks more mass is closer in, planets indeed might be formed close to the star within the iceline (Hatzes & Wuchterl 2005).

The problem to form planets in close binaries by both the gravitational instability and the core accretion scenario clearly demonstrates that planets detected in these systems are most intriguing objects. They provide the possibility to study the effect of stellar multiplicity on the planet formation, the longterm stability and evolution of planetary orbits and yield ancillary conditions for the formation of Jovian planets.

So far only few programs have searched for additional visual companions of exoplanet host stars. Adaptive optics (AO) imaging search campaigns reported several new close companions during the last years. Patience et al. (2002) detected companions close to HD 114762 and τ Boo. Furthermore Els et al. (2000) reported a faint companion, separated from the exoplanet host star Gl 86 by $\sim$2 arcsec. They concluded from infrared photometry that this companion is a late L or early T dwarf. Queloz et al. (2000) reported a longterm linear trend in the radial velocity of Gl 86 and according to Jahreiß (2001) Gl 86 turned out to be a highly significant $\Delta\mu$ binary after combining Hipparcos measurements with ground based astrometric catalogues. Both results indicating that Gl 86 has a companion of stellar mass. Mugrauer & Neuhäuser (2005a) could finally prove that the companion, firstly detected by Els et al. (2000), is indeed a white dwarf, the first white dwarf found close to an exoplanet host star.

Despite being successful, AO imaging surveys cannot find wide companions with separations up to a few thousand AU because of their small field of view (typically only a few tens of arcsec). Lowrance et al. (2002) presented a new wide (750 AU) low-mass stellar companion ($\sim$0.2M$_\odot$) which was detected in the digitized plates of the Palomar Obervatory Sky Survey, a first example that there could be many more of these objects, all with separations larger than 100 AU. The whole sample of exoplanet host stars was not systematically surveyed so far for these objects, i.e. the multiplicity of exoplanet host stars might be much higher than derived from AO surveys alone. Therefore, we have started a search program for wide companions of exoplanet host stars and several new binaries were already detected (see Mugrauer et al. 2004 a,b and 2005 b).

Most of the exoplanet host stars have large proper motions ($\mu\sim$200 mas/yr), well known due to precise measurements of the *HIPPARCOS* satellite (Perryman et al. 1997). Therefore, real companions can be identified as co-moving objects by comparing images taken with several years of epoch difference. Photometry and spectroscopy can then confirm the companionship — the measured photometry of the companion must be consistent with an object of the given spectral type at the distance and age of the exoplanet host star. To be sensitive to low-mass faint substellar companions, we observed all targets in the near-infrared (H band at 1.6 μm), as substellar companions are several magnitudes brighter compared to the visible spectral range. Furthermore, the contrast between the hot primary and a substellar companion is smaller in the infrared. Hence, close companions separated from their primary star by only a few arcsec, can be detected.

At the beginning of 2002 we started our multiplicity study of exoplanet hosts stars in the northern sky with a first imaging campaign carried out at the Calar Alto observatory (Spain). We selected as targets all exoplanet host stars, published before 2002 and which are observable with small airmasses (AM $\leq$ 1.5) from Calar Alto (37° latitude), i.e. in total 44 exoplanet host stars. The first observations were obtained in February 2002 followed by a further observing run in July 2002. The third and final run was scheduled for September 2002 but clouded out and no data could be taken. In total we have observed 18 exoplanet host stars. Most of the remaining 26 stars were observed in the meantime with either UKIRT[1] on Hawaii and/or NTT[2] on La Silla.

2. The Calar Alto Survey - Results

Our direct imaging campaign was carried out with the 2.2m telescope at the Calar Alto observatory, using the near-infrared imager MAGIC. This camera is equipped with a 256x256 HgCdTe-detector with a pixelscale of 640 mas in its high resolution mode, i.e. 164x164 arcsec field of view.

All MAGIC images were astrometrically calibrated using the 2MASS[3] Point source catalogue (Cutri et al. 2003), yielding the detector pixelscale and the offset in the position angle (PA). The results of the astrometric calibration for both MAGIC runs are summarized in Table 1.

Table 1. Astrometric calibration of all observing runs.

epoch	pixelscale [mas/pixel]	offset PA [$^\circ$]
02/02	640.2$\pm$3.8	0.01$\pm$0.19
07/02	639.1$\pm$3.8	-0.21$\pm$0.26

Because most of the observed exoplanet host stars are nearby relatively bright stars the integration time had to be reduced to only a few tenth of a second, in order to avoid saturation effects of the detector. Many of these short exposures were averaged to one frame with a total integration time of

[1] United Kingdom Infrared Telescope
[2] New Technology Telescope
[3] 2 Micron All Sky Survey

Table 2. Summary of the Calar Alto Survey. For each observed exoplanet host star we list the total exposure time, the measured seeing, the inner and outer detection radii of stellar companions, and the mass limit of detectable objects.

star	time [min]	seeing [arcsec]	r_{in} [AU]	r_{out} [AU]	mass limit [M_{Jup}]
47 UMa	30	2.4	107	946	53
55 Cnc	30	1.0	59	810	37
BD−10°31666	9	1.7	369	4287	72
HD 8574	30	1.0	314	2741	56
HD 10697	30	1.2	261	2042	56
HD 37124	25	1.6	239	2298	62
HD 38529	26	1.7	433	2933	66
HD 46375	26	1.4	190	2138	65
HD 50554	30	1.3	199	2105	63
HD 52265	33	1.1	154	1904	54
HD 74156	32	1.5	516	4256	70
HD 80606	31	1.1	321	2877	66
HD 82943	27	1.2	179	1775	55
HD 92788	30	1.7	223	2089	61
HD 106252	33	1.4	251	2396	63
HD 136118	30	1.2	403	3412	63
HD 114762	23	1.5	316	2674	66
HD 209458	24	1.0	235	3073	59

$\sim$ 3 minutes. The telescope was then moved by a few arcsec and the integration procedure was repeated. With this jitter observing technique the bright infrared sky background could effectively be subtracted from the images. To correct for the individual pixel sensitivity all frames were flatfielded using sky flat frames which were taken at the beginning of the night in twilight. Background subtraction, flatfielding, image registration, shifting and final averaging of all images were achieved with the data reduction package ESO eclipse [4] (Devillard 2001).

The achieved observational data of all exoplanet host stars observed with MAGIC in the two observing runs carried out in January and July 2002 are summarized in Table 2. We list the total integration time per target (*time*) and the average seeing measured in each MAGIC image (*seeing*). In general, after 30 min of integration a detection limit (S/N = 3) of H = 18 mag was reached. With the given distances of the exoplanet host stars we can convert the detection limits to the absolute magnitudes of the faintest detectable companions. The mass of these companions can be approximated with theoretical models, using mass-magnitude relations therein. With Baraffe et al. (2003) models and an average system age of 5 Gyr we estimate to be sensitive to substellar companions down to $\sim 60\,M_{Jup}$. Table 2 shows the derived mass limit of any detectable companions as well as the inner and outer detection radii (r_{in}, r_{out}) of stellar companions in all MAGIC images. The inner limit depends on the brightness of the primary and on the seeing. The outer radius is only limited by the MAGIC field of view. In average additional stellar companions can be detected around all targets in a range of separations between about 270 AU and 2500 AU.

[4] ECLIPSE: ESO C Library for an Image Processing Software Environment

As a typical example, we plot in Fig. 1 the achieved detection limit as a function of separation to the exoplanet host star HD 52265. Stellar companions can be detected from 5.5 arcsec (154 AU) up to 67.8 arcsec (1904 AU). A limiting magnitude of 17.9 mag is reached beyond 14 arcsec (393 AU). This is about $\sim$ 1.5 mag deeper than the 2MASS detection limit, i.e. all objects detected in 2MASS are also visible in our MAGIC images. However close and faint companions around all these stars are not accessible for our wide field imaging. For example with AO imaging Patience et al. (2002) could detected a close companion of HD 114762 (H $\sim$ 13.4 mag) which is located only 3.3 arcsec north-east of the exoplanet host star. This object is not visible in our MAGIC image as expected from the derived detection limit.

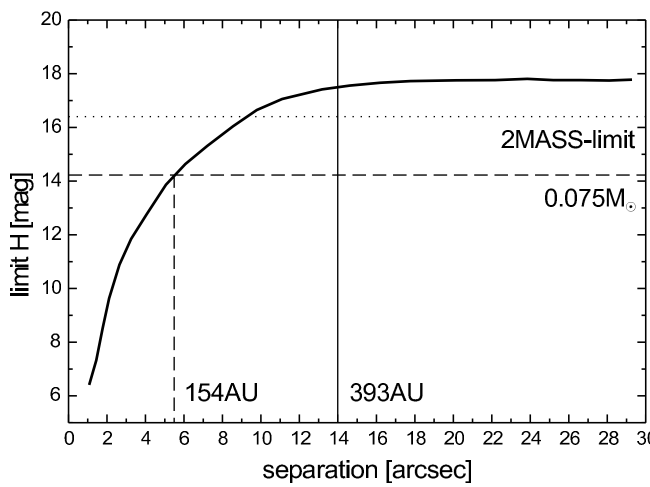

Fig. 1. The achieved MAGIC detection limit (S/N = 3) for a range of separations to the exoplanet host star HD 52265. Beyond 14 arcsec (393 AU), where the noise is dominated by the background, the sensitivity goes down to H = 17.9 mag (see solid line). According to Baraffe et al. (2003) models, the limiting magnitude enables the detection of substellar companions down to $54\,M_{Jup}$, assuming a system age of 5 Gyr. Further stellar companions can be ruled out between 154 AU and 1904 AU in projected separation (see dashed lines). The 2MASS detection limit is shown as a dotted line.

Because real companions of the exoplanet host stars are co-moving to their parent stars, i.e. both objects form a common proper motion pair, they can be distinguished from unrelated slow or non-moving background stars. By comparing all our MAGIC images with images from 2MASS and POSS[5] I and II, the companionship of all detected objects in the MAGIC images can be checked. Among the 18 observed exoplanet host stars, no further so far unknown co-moving companions could be detected around the target stars.

However our sample contains four systems which are listed as binaries in the Washington Visual Double Star (WDS) catalog (Worley 1997). The MAGIC images of these four systems are shown in Fig.2. The measured separations and position angles are summarized in Table 3 together with the distances of the exoplanet host

[5] Palomar All Sky Survey

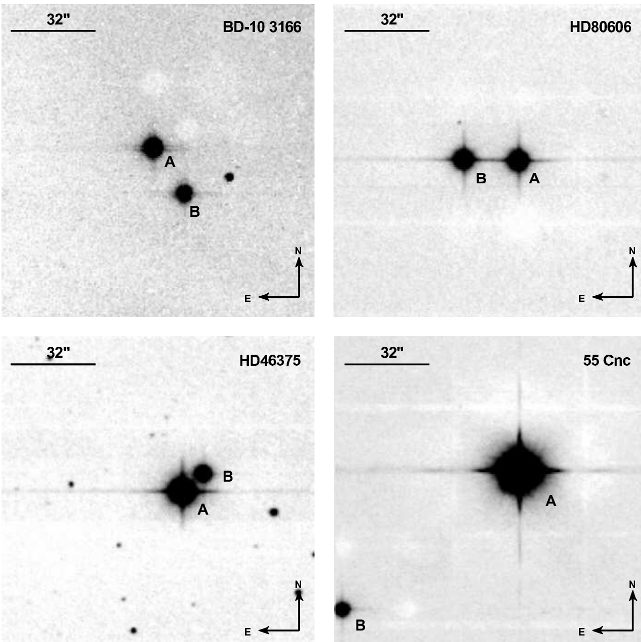

Fig. 2. The four wide WDS binaries among the exoplanet host stars observed with MAGIC at the Calar Alto 2.2m telescope. The system BD$-10°$3166 turns out to be only a visual double star (see section 3 for details).

stars. Thereby the distances of HD 80606, 55 Cnc and HD 46375 can be derived from Hipparcos parallaxes (Perryman et al. 1997). BD$-10°$3166 is not listed in the Hipparcos catalogue therefore no accurate parallax is available for this star. To estimate the distance of BD$-10°$3166 we use its spectral type, K0V, derived by Butler et al. (2000), as well as photometric data in different filters (B = 10.727$\pm$0.081 mag, V = 10.000$\pm$0.044 mag[6], J = 8.611$\pm$0.032 mag, H = 8.300$\pm$0.040 mag, and K_S = 8.124$\pm$0.026 mag[7]). The apparent photometry of BD$-10°$3166 is consistent with a K0V dwarf at a distance of 67$\pm$3 pc.

Table 3. The astrometry of the four WDS binary systems, observed with MAGIC. We show the separations and position angles for all systems, measured in the MAGIC images. In addition we list the distance of the four exoplanet host stars which are all determined with Hipparcos parallaxes, expected BD$-10°$3166 whose distance is derived using the spectral type of the star and its apparent magnitudes.

star	distance [pc]	separation [arcsec]	PA [°]
HD 80606	58	20.549$\pm$0.122	88.66$\pm$0.20
HD 46375	34	10.352$\pm$0.061	309.95$\pm$0.31
BD$-10°$3166	67	20.891$\pm$0.124	214.21$\pm$0.29
55 Cnc	13	84.715$\pm$0.503	128.10$\pm$0.30

The proper motions of both components of the four observed WDS binaries are already given by the Hipparcos, the USNO-B1.0 (Monet et al. 2003) and the UCAC2 catalogues (Zacharias et al. 2004). Only the secondary of HD 46375 is not listed in any of these catalogues. HD 46375 is not well resolved in the POSS images but the companion is clearly separated from the bright primary star in the 2MASS image. By comparing this image with our MAGIC image we can derive the proper motion of HD 46375 B with precision which is limited mainly by the 2MASS astrometric accuracy. We summarize the proper motions of the four WDS binaries in Table 4.

Table 4. Proper motions of the four WDS binary systems observed with MAGIC. The proper motion of all primaries as well as three of the four secondaries are already published by Hipparcos (HIP), USNO-B1.0 and UCAC2 catalogues. The proper motion of HD 46375 B was derived by comparing the 2MASS image with our MAGIC image.

star	$\mu_{\rm Ra}$ [mas/yr]	$\mu_{\rm Dec}$ [mas/yr]	reference
HD 80606 A	46.98$\pm$6.32	6.92$\pm$3.99	HIP
HD 80606 B	42.80$\pm$9.32	8.26$\pm$5.88	HIP
HD 46375 A	114.24$\pm$0.92	-96.79$\pm$0.73	HIP
HD 46375 B	134$\pm$45	-128$\pm$43	MAGIC-2M
BD$-10°$3166 A	-186.8$\pm$1.6	-6.2$\pm$1.3	UCAC2
BD$-10°$3166 B	-198.8$\pm$4.4	-93.0$\pm$4.4	UCAC2
55 Cnc A	-485.48$\pm$0.98	-234.40$\pm$0.78	HIP
55 Cnc B	-488$\pm$6	-234$\pm$5	USNO-B1.0

The 2MASS point source catalogue provides accurate near infrared photometry of the secondaries and Kharchenko (2001) lists V band magnitudes for HD 80606 B and BD$-10°$3166 B. The V band magnitudes of 55 Cnc B and HD 46375 B are listed in the WDS catalogue but no photometric uncertainties are given there (see Table 5).

Table 5. Photometric data of the secondaries of the four WDS binaries observed with MAGIC. We list the J, H and K_S near-infrared magnitudes taken from the 2MASS point source catalogue. All V band magnitudes with given uncertainties are taken from Kharchenko (2001). The V magnitudes of HD 46375 B and 55 Cnc B are listed in the WDS catalogue but without uncertainties.

companion	J [mag]	H [mag]	K_S [mag]	V [mag]
HD 80606 B	7.798$\pm$0.029	7.509$\pm$0.029	7.389$\pm$0.021	9.090$\pm$0.022
HD 46375 B	8.701$\pm$0.034	8.083$\pm$0.053	7.843$\pm$0.021	11
BD$-10°$3166 B	9.512$\pm$0.023	8.965$\pm$0.022	8.640$\pm$0.021	14.437$\pm$0.153
55 Cnc B	8.560$\pm$0.027	7.933$\pm$0.040	7.666$\pm$0.023	13.16

3. Discussion

We observed 18 exoplanet host stars with MAGIC at Calar Alto. New co-moving companions could not be detected but 4 binary systems were observed which are already listed in the

[6] B,V magnitudes from Kharchenko (2001)
[7] J,H,K_S from the 2MASS point source catalogue

Washington Visual Double star catalogue (WDS). The proper motions of the primary and the secondary components of these binary systems are summarized in Table 4. Both components of the WDS binaries HD 80606, HD 46375, and 55 Cnc share a common proper motion. Therefore the companionship of these systems is confirmed by astrometry.

The WDS binary BD$-10°$3166 consists of two high proper motion stars which exhibit proper motions being similar in right ascension (Ra) but significantly differ in Declination (Dec). According to the astrometric UCAC2 catalogue (see Table 4) the motion of the secondary relative to the primary is -12 ± 4.7 mas/yr in Ra but -86.8 ± 4.6 mas/yr in Dec, i.e. a total relative motion of 87.6 ± 4.6 mas/yr. Comparing our MAGIC image with the 2MASS and the POSS-I and POSS-II images yields a similar result. We derive a motion of the secondary relative to the primary component of -13 ± 7 mas/yr in Ra and -79 ± 7 mas/yr in Dec. Therefore we can conclude that this WDS binary is clearly not a common proper motion pair.

In a next step we can test the companionship of the four WDS binaries with photometry. We derive the absolute magnitudes of the four secondaries using their apparent magnitudes. Thereby we always assume that the companions are located at the distances of the exoplanet host stars, as it is expected for real companions. For all secondaries accurate 2MASS near infrared photometry is available and Kharchenko (2001) provides V band magnitudes of HD 80606 B and BD$-10°$3166 B. The V band magnitudes of 55 Cnc B and HD 46375 B (photometric uncertainties are not available) are listed in the WDS catalogue (see Table 5). We plot all secondaries in a J-K_S, M_H diagram (upper panel of Fig.3), together with comparison dwarfs from the Hipparcos catalogue, the Nearby Stars catalogue (Gliese & Jahreiß 1995), and cool dwarfs from Cruz et al. (2003). Only comparison objects with accurate colors ($\sigma(\mathrm{J}-\mathrm{K_S}) < 0.05$) and accurate absolute magnitudes ($\sigma(\mathrm{M_H}) < 0.25$) are plotted. Furthermore we plot all secondaries in a V-K_S, M_{K_S} diagram (see bottom panel of Fig.3), using again the same Hipparcos comparison dwarfs as in the infrared color-magnitude diagram, as well as M dwarfs from Leggett et al. (1992).

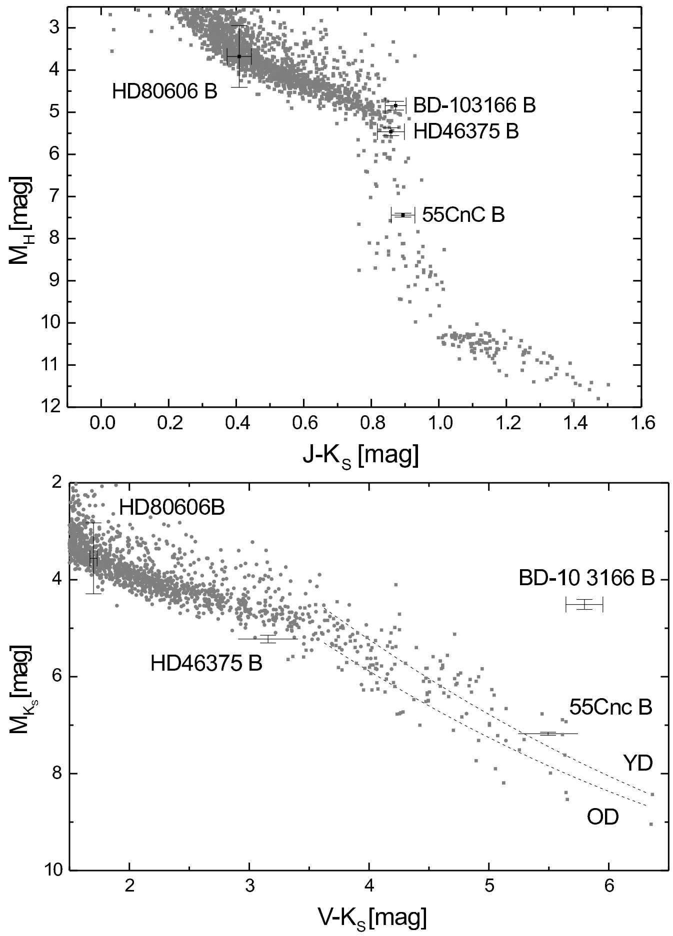

Fig. 3. The photometric test of companionship of the four WDS binary systems. We plot the four secondaries in a J-K_S, M_H (top panel) and a V-K_S, M_{K_S} diagram (bottom panel). The absolute magnitudes of the secondary stars are derived with their apparent magnitudes and the distances of the exoplanet host stars. For comparison we show colors and absolute magnitudes of dwarfs taken from the Hipparcos catalogue, the Nearby Stars catalogue (Gliese & Jahreiß 1995), and from Cruz et al. (2003). We select only those dwarfs for which accurate photometric data are available ($\sigma(J-K_S) < 0.05$ mag, $\sigma(M_H) < 0.25$ mag). In the bottom panel we use the same Hipparcos comparison dwarfs as in the upper plot (filled circles). In addition we plot young and old disk dwarfs (filled squares) from Leggett et al. (1992) together with the least-square fits (dashed lines) for these two dwarf populations, as derived by Leggett et al. (1992). The V band magnitude of HD 46375 B and 55 Cnc B are taken from the WDS catalogue but no V band uncertainties are published there. This is illustrated with open error bars. The photometry of BD$-10°$3166 B is inconsistent with a dwarf located at the distance of the exoplanet host star but fully comply with a M4 to M5 dwarf located only at a distance of 13 pc, i.e. it is just an unrelated foreground object.

Table 6. Summary of all photometric data which are shown in Fig. 3. We list the J-K_S colors as well as the absolute H and K band magnitudes of the companions derived from the apparent 2MASS magnitudes and the known distances of the exoplanet host stars. The V-K_S color is derived with K_S from 2MASS and V band magnitudes taken either from Kharchenko (2001) or from the WDS catalogue (see also Table 5).

companion	J-K_S [mag]	M_H [mag]	V-K_S [mag]	M_{K_S} [mag]
HD 80606 B	0.409 ± 0.036	3.678 ± 0.732	1.701 ± 0.03	3.558 ± 0.731
HD 46375 B	0.858 ± 0.040	5.464 ± 0.094	3.157	5.224 ± 0.081
BD$-10°$3166 B	0.872 ± 0.031	4.835 ± 0.103	5.797 ± 0.154	4.510 ± 0.103
55 Cnc B	0.894 ± 0.035	7.443 ± 0.046	5.494	7.176 ± 0.033

According to the intrinsic colors for dwarfs and giants published by Tokunaga (2000) the V-K_S and J-K_S colors of BD$-10°$3166 B are both fully consistent with a M4 to M5 dwarf. Nevertheless if we assume that this object is indeed located at the distance of the exoplanet host star the derived absolute K_S band magnitude is about 3.5 mag brighter than

comparison dwarfs with the same V-K_S color (see the bottom panel of Fig. 3), i.e. the distance of this object is overestimated by a factor of 5. The apparent infrared and V band photometry of BD$-10°$3166 B is consistent with a M4 to M5 dwarf located at a distance of about 13 pc. Therefore we can conclude that the WDS binary BD$-10°$3166 is only a visual pair of stars, consisting of a K0 dwarf in the background at a distance of 67 pc and an unrelated foreground M dwarf at a distance of about 13 pc.

As it is illustrated in the color-magnitude diagrams shown in Fig. 3 the photometry of the secondaries of the common proper motion pairs HD 80606, HD 46375 and 55 Cnc is consistent with dwarfs located at the distances of the exoplanet host stars, hence the companionship of the these three WDS binaries is confirmed by both astrometry and photometry.

The masses of the three secondaries HD 80606 B, 55 Cnc B, and HD 46375 B can be derived by converting their absolute infrared magnitudes to masses, using the evolutionary Baraffe et al. (1998) models. Thereby we always assume a system age of 5 Gyr, which is a good estimate for most of the exoplanet host stars. It is important to mention that, the age uncertainty of the binary systems in the order of a few Gyr is not important here because for system ages between 1 and 10 Gyr the infrared magnitudes of stars with masses below one solar mass are not strongly age dependant. The derived companion masses range from $0.9\,\mathrm{M}_\odot$ to $0.27\,\mathrm{M}_\odot$, with mass ratios ($\mathrm{M_c}/\mathrm{M_p}$) between 0.3 to 0.87.

Table 7. Summary of derived properties of the binary systems. For all three binaries imaged with MAGIC we show their projected separations, derived from the angular separation and the distance of the system, and the masses of primary ($\mathrm{M_p}$) and secondary $\mathrm{M_c}$. For each system we show the critical semi-major axis for a circular and an eccentric (e = 0.8) binary orbit, respectively. The primary masses are all derived by Santos et al. (2004).

companion	sep. [AU]	$\mathrm{M_p}$ [$\mathrm{M_\odot}$]	$\mathrm{M_c}$ [$\mathrm{M_\odot}$]	$\mathrm{a_{c,e=0.0}}$ [AU]	$\mathrm{a_{c,e=0.8}}$ [AU]
HD 80606 B	1200±404	1.04	0.904±0.147	345	45
HD 46375 B	346±13	0.82	0.576±0.013	106	14
55 Cnc B	1062±13	0.87	0.265±0.006	399	49

Finally with the measured angular separations and known distances of the binary systems we can derive their projected separations. Because neither the orientation of the binary orbit to the line of sight nor the position of both stars on their orbits around their common barycenter is known, we always use the observed projected separation also as estimate of the binary semi-mayor axis. The separation of the three binaries range from 350 up to 1200 AU.

According to Holman & Wiegert (1998) objects, e.g. additional companions, located in a binary system are only longterm stable if their semi-major axes do not exceed a critical value, the critical semi-major axis ($\mathrm{a_c}$), which depends on the binary semi-major axis, its eccentricity as well as its mass-ratio. The critical semi-major axes of possible additional companions in the three binary systems are listed in Table 7. They range from about 400 AU for an assumed circular binary orbit down to only 10 AU for an eccentric binary system, respectively. Our observations didn't reveal any further, wide co-moving companions in these systems, as expected from the Holman & Wiegert (1998) stability criteria.

Eggenberger et al. (2004) have recently compared the statistical characteristics of planets in binary systems with those orbiting single stars. They found that the distribution of the masses of binary-star planets with periods shorter than 40 days is approximately flat, whereas single-star planets all exhibit masses less than $2\mathrm{M_{Jup}}$. Furthermore, Eggenberger et al. (2004) found that all known close binary-star planets have almost circular orbits (e<0.05), while eccentric orbits are only detected among single-star planets.

However, these statistical differences are based only on a small number of known binary-star planets, and therefore the significance of these differences is still not clear. Note that the whole sample of the exoplanet host stars has not been systematically surveyed so far for close or wide companions. Only systematic search programs for companions can clarify the multiplicity status of the stars in the sample.

In our study we have already shown that there are indeed several exoplanet host stars considered as single stars in the published statistical analyses which emerge as binary systems (see e.g. Mugrauer et al. 2005b). A further example of these former unknown or unconfirmed binary systems among the exoplanet host stars is HD 46375, whose binary nature was confirmed here for the first time with astrometry as well as photometry. The exoplanet in that binary system was detected by Marcy et al. (2000). It is a hot Jupiter (Msin(i) = $0.249\,\mathrm{M_{Jup}}$) which revolves its parent star in only 3.024 days on an almost circular (e = 0.04) orbit, typical for such a short period binary-star planet.

The Calar Alto imaging survey was just the beginning of our multiplicity study of the exoplanet host stars, using a 2 m class telescope. Only a relative small number of exoplanet host stars was observed. We expanded our search for additional wide companions of exoplanet host stars, using larger mirrors to be sensitive to fainter companions. On the northern sky we use the UKIRT on Hawaii and southern targets are observed with the NTT on La Silla, and since begin of 2005 also with the VLT on Paranal. The results of these surveys finally will clarify the multiplicity status of most of the exoplanet host stars and will verify the significance of the reported statistical differences between single-star and binary-star planets.

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